



# Shipping sheep or creating cattle: domesticate size changes with Greek colonisation in Magna Graecia



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## ABSTRACT

This study presents the evidence for an increase in the size of livestock concurrent with Greek colonisation in the region of southern Italy referred to by the Romans as Magna Graecia. Biometrically distinct varieties of sheep and cattle are identified from sites of ancient Greece. Through biometric comparisons these varieties are distinct and distinguishable from those of pre-colonisation sites in southern Italy. The size of these livestock is shown to increase following the foundation of Greek colonial settlements in the area. Whether through domesticate translocation or local improvements the process of Greek colonisation in Magna Graecia is shown to have had a significant impact on local livestock populations in colonisation areas of southern Italy.

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## 1. Introduction

Greek colonisation in the Mediterranean was an intricate and multi-varied process. The speed of colonial foundations coupled with their blended hellenic architecture and material culture suggest the settlement of persons from multiple areas of Greece and possibly also of non-Greek origin (Antonaccio, 2001:127; Kelley, 2012:426; Lucy, 2005:101; Owen, 2005:13). The degree of organisation in the process of settlement foundation, as well as the intensity and nature of interactions with local cultural groups, remain hotly debated.<sup>1</sup> As with any study of human movement and cultural interactions, these debates have in recent decades benefited from the inter-disciplinary collaboration of multiple lines of inquiry. This study provides some insights into the supplemental potential of zooarchaeological techniques in the examination of colonies and colonial interactions of southern Italy – a region referred to by the later Romans as *Magna Graecia* (“Greater Greece”). More specifically, the utility of domesticate biometry is explored for identifying changes to livestock biometry concurrent with Greek settlement in this area.

This study builds upon the many analyses of livestock from the Roman period, which see an increase in the size of domesticates in areas under Roman control (i.e. Albarella et al. 2008; Colominas et al. 2013; Lepetz, 1996; MacKinnon, 2010). The reasons for this are still debated, and are not addressed here. Additional investigations have been conducted on the changing size of livestock in post-Roman periods (mainly Medieval and post-Medieval),<sup>2</sup> but comprehensive comparative biometric studies are still largely lacking for the preceding Bronze and Iron Ages.<sup>3</sup> Roman livestock studies have yet to inspire a reappraisal of domesticate size changes concurrent with earlier identified cultural expansions.

### 1.1. Livestock in ancient Greece

Livestock production is occasionally referenced by classical sources, often as an elite or aristocratic activity. The Homeric epics (c. eighth century BC) give descriptions of areas of Greece as ‘rich in flocks’, as well as numerous references to the large flocks and herds kept by elite individuals.<sup>4</sup> While these texts identify livestock as sources of wealth and status, indications of breed or other physiological variation are only tangentially alluded to (i.e. *Odyssey*

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<sup>1</sup> For an overview of recent debates as to the process of Greek colonisation see Antonaccio (2001, 2007); De Siena (1990) for southern Italy and Babić (2007); Dietler (2005, 2010); Hodos (2006); Malkin (2011); Owen (2005); Shepherd (2009); Sommer (2011); Stein (2005); Van Dommelen (2005); Wilson (2006) for Greek colonisation in general.

<sup>2</sup> See for example Albarella 1997; Davis and Beckett 1999; Thomas 2005; Thomas et al. 2013.

<sup>3</sup> Although see De Grossi Mazzorin (1995); Elevelt (2012); Kron (2002).

<sup>4</sup> *Iliad* 2.106, 2.605, 2.696, 2.705, 9.154, 9.446, 14.490, 16.417; *Odyssey* 11.257, 15.226.

18.371, describing plough oxen, “the best kind, reddish and large, and fed well with grass”).

**Hesiod** (c. seventh century BC) mentions the thick fleeces of his sheep (*Works and Days* 235; 518). The sixth century BC tyrant Polykrates of Samos is reported to have admired the fine wool of sheep from Athens, with the desire to import Athenian sheep to cross-breed with his existing Milesian variety (**Athenaeus** 12.540d). **Aristotle** (*Historia Animalium*, fourth century BC) alludes to regional types of dairy cattle (3.21), as well as sheep of broad-tailed and ‘shaggy’ varieties (7.8); different breeds (as ‘breeds’ carry connotations of phenotypic homogeneity, the term ‘varieties’ will hereafter be used) outside Greece are also described (7.28).

The presence of Greek varieties of livestock in southern Italy is described from at least the Roman period.<sup>5</sup> Greek livestock are mentioned mainly in relation to types of sheep; the so-called ‘jacketed’ or fine-fleeced sheep. Columella identifies the Calabrian, Apulian and Milesian varieties as of ‘outstanding excellence’ and Tarentine as the best of all (**Columella** 7.2.3).<sup>6</sup> **Pliny** (*Natural History* 8.190) asserts that the best wool comes from Apulia, which in Italy was referred to as that of the Greek sheep.

These references, though sparse, appear to indicate the presence of regional varieties of livestock (namely sheep) in at least Greece and Italy. From Roman descriptions it appears that local varieties of sheep, perceived as ‘Greek’ were either translocated to southern Italy with Greek colonists, or were locally developed at some point prior to the writings of Columella and Pliny in the first century AD. Unfortunately, from the surviving references it is not possible to determine specifically if these sheep were considered Greek due to a difference in their morphology/appearance, or simply because they were kept in the region referred to by the Romans as Magna Graecia. Studies by **Ryder** (1983) suggest the development of distinct breeds of ‘Greek’ fine-fleeced sheep from at least 500 BC (on the basis of sculptural representations) which he states were spread around the Mediterranean by colonists (**Ryder**, 1983:141, 150). These ‘Greek sheep’ however remain to be more specifically defined.

If Greek livestock described from southern Italy were morphologically distinct varieties in comparison with those present in southern Italy prior to colonisation, this would suggest either a translocation of livestock or a change in their management (local improvement) associated with or following Greek settlement.

## 1.2. Livestock biometry and Greek colonisation

Textual references to the presence of ‘Greek’ livestock in Magna Graecia suggest that the incorporation of domesticated biometry<sup>7</sup> into studies of colonial interaction would permit a new line of evidence through which to examine both the process of Greek colonisation and contacts between colonial and indigenous groups. Chronological comparisons of domesticated biometry between sites in Greece and Italy (including but not limited to colony sites) could be used to determine not only if and when these ‘Greek’ livestock were developed, but also how prevalent they were in Greek colonies and their hinterlands and the speed at which their presence could be established following the currently accepted chronology

of Greek settlement in Italy. Such comparisons would provide hitherto unexplored avenues of investigation into both the organisation of early colonial settlement and colonial interactions. The degree and nature of colonial contacts in Magna Graecia would be difficult to distinguish purely from evidence of changes to livestock, but when taken in conjunction with other lines of evidence should further illuminate inter-cultural interactions.

Given the surviving textual references to Greek livestock, there is no *a priori* reason why domesticated biometry should be ignored for the Greek period. Although zooarchaeology is becoming a reasonably standard area of research within Greek and Italian archaeology – albeit with a lesser focus on the early historic periods (**Kotjabopoulou and Gamble**, 2003:35) – biometrical recording is still not routinely employed. In those instances where measurements are taken they are often under-utilised or simply reported.

Tangential references noted by this author suggested that either Greek livestock were ‘improved’ (increased in body size) at a point in Greek antiquity (**Friedl**, 1984:35) or that certain larger faunal remains at non-Greek sites were indicative of Greek livestock (**Bökönyi**, 2010:19–20; **Kron**, 2002:175). This ‘enlarged’ Greek livestock was mentioned but no data could be found which coherently examined evidence for its existence. These references, coupled with those from surviving texts, demanded a comprehensive comparative examination of livestock biometry in line with those already conducted for the subsequent Roman and later periods. The following analysis of biometrical data from Greek and Italian sites investigates the veracity and implications of what was previously only alluded to – and through these Greek domesticated varieties demonstrates the use of (and need for) comprehensive multi-site investigations of livestock biometry in ancient Greece and known or putative areas of colonisation.

## 2. Livestock of Greece and Magna Graecia

Biometric data used for this study were obtained from three site categories. Data was collected from (1) sites in disparate regions of ancient Greece, (2) Greek colonies in southern Italy and (3) geographically proximate non-colony sites from pre- and post-colonisation periods of southern Italy. The details of these sites are given in **Table 1**, and their locations given in **Fig. 1**. The site samples considered here come from a range of contexts and assemblage sizes.

The wide geographical spread of Greek samples was chosen to provide a regional overview of livestock biometry for this area. The disparate regions chosen demonstrate an overall view of the size of Greek livestock during the periods discussed. While only a few comparative sites were available for this study, a future increase in the use of biometric data recording and analysis will only serve to enhance our understanding of livestock varieties in ancient Greece. Many of the available sites are sanctuaries. These include the Artemis sanctuaries at Olympia and Kalapodi (Artemis and Apollo), Poseidon sanctuaries at Tenos and Kalaureia and the Kabirien sanctuary near Thebes. These samples contain faunal material from consumptive activities in and around the sanctuary complexes, although in some cases do relate directly to an altar (as at Kalapodi and Artemision Olympia). These samples demonstrated no distinct biases for a particular age group or sex when compared with settlement sites. The sanctuaries studied likely obtained sacrificial animals from their hinterlands, or possibly from the surrounding region. They therefore represent a palimpsest of local livestock populations. In this way, the combination of sanctuary and settlement data used for this study benefits rather than hinders our investigation of Greek livestock.

<sup>5</sup> See **Kron** (2002) for a discussion of Roman textual sources on livestock.

<sup>6</sup> Calabria and Apulia are regions of southern Italy. Milesian sheep would have come from the Greek city of Miletus on the modern-day Turkish coastline, and Tarentine sheep would have come from the area of Tarentum (modern Taranto) in southern Italy.

<sup>7</sup> Biometry, in this instance, is the comparison of measurements taken from the remains of animals recovered from archaeological sites. It is through the comparison of these measurements that changes in the body size of livestock populations can be assessed.

**Table 1**

**Sites** used in this study. Sites are ordered here by first by the country in which they are located, followed by their cultural ascription and then chronologically by sample. The abbreviation used here of “c. BC” denotes ‘century BC.’ The use of the category ‘colonial’ here is used to identify those sites (Incoronata and Pomarico Vecchio) which occur in the vicinity of identified Greek colonies and date after the point at which colonisation began in this region. <sup>a</sup>The beginning of colonisation in southern Italy, like much of the process of Greek colonisation in southern Italy, remains an open debate. The official date for the first colonial foundation in this area is the (middle) 8th century BC, although imported ceramic evidence in some settlements of this region suggests this may have begun in the 9th century BC (Coldstream, 1994:49; D’Andria, 1990:282; Ridgeway, 2004:29; Stocker, 2009:145,220).

Region	Site	Period	Dating	Source
Greece	Tiryns	Late Helladic IIIB-C	14th–12th c. BC	von den Driesch and Boessneck 1990
	Kalapodi	Late Helladic-Submycenaean	12th–11th c. BC	Stanzel 1991
	Artemision Olympia	Protogeometric-Classical	10th–4th c. BC	
	Poseidon Kalaureia	Late Archaic	-	Benecke 2006, unpublished
	Kabiren bei Theben	Archaic-Classical	7th–4th c. BC	Author; Penttinen <i>et al</i> 2009
	Messene	Classical-Hellenistic	c.6th–4th c. BC	Boessneck 1973
	Kassope	Archaic-Hellenistic	8th–3rd c. BC	Nobis 1994
Southern Italy	Poseidon a Tenos	Hellenistic	4th c. BC	Friedl 1984
	Termitito	Late Bronze Age	14th–11/10th c. BC	Leguilloux 1999
	Torre Mordillo	Late Bronze Age	13/12th–11/10th c. BC	Bökönyi 2010
	Timpone della Motta	Early Iron Age	11th–8th c. BC	Tagliacozzo & Curci 2001
	Incoronata	Archaic	8th–6th c. BC	Elevelt 2012
	Pomarico Vecchio	Hellenistic	4th c. BC	Bökönyi 2010
	Eraclea Lucana	Archaic-Hellenistic	7th–4th c. BC	Aimar 1997
Greek Colonies	Pantanello	Classical-Hellenistic	6th–3rd c. BC	Wilkens & Delusso 2002
				Bökönyi 2010

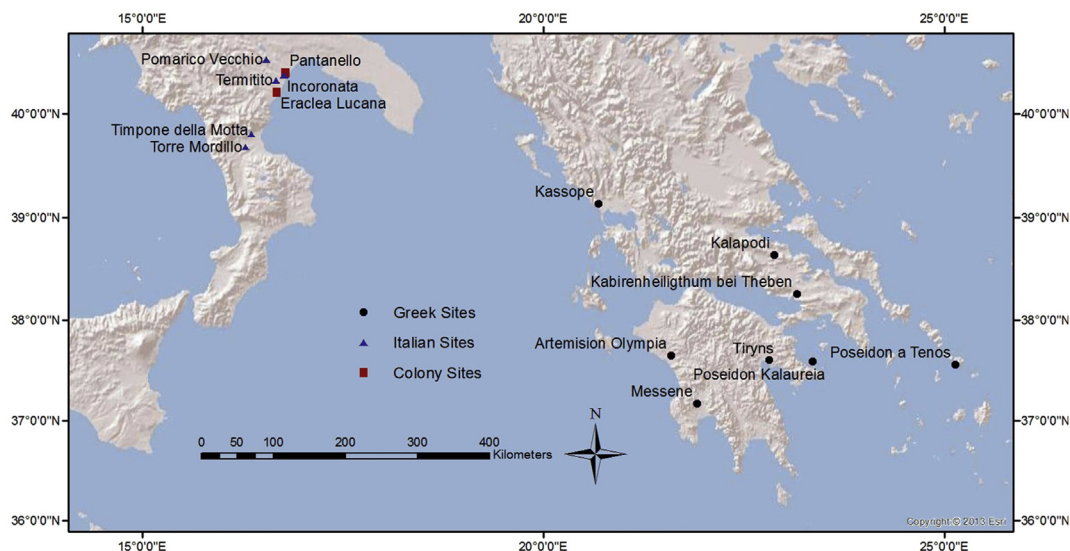
The settlement of Tiryns is located 2 km north of the town of Nauplion just inland from the northern margins of the Gulf of Argolid. During the Late Bronze Age (Late Helladic – c.1600–1150 BC following Burns, 2010) Tiryns was a major Mycenaean palatial centre. Faunal material from the 1976–1983 excavations in the lower citadel area was analysed and published by von den Driesch and Boessneck (1990). Measures from the Late Helladic IIIB-C samples were used in this study.

The sanctuary complex of Kalapodi is located in Phocis near to this region's border with Boetia and roughly 1 km east of the village of Kalapodi. Occupation and use material was excavated in 1973 dating from the Late Helladic/Submycenaean (12th–11th centuries BC) to later Byzantine (c. AD 1450) periods. Faunal material from these excavations was analysed and published by Stanzel (1991) under the direction of von den Driesch. Measures from the Late Helladic/Submycenaean (12th–11th centuries BC) and Protogeometric-Classical (10th–4th centuries BC) were used in this study.

The area around the altar of Artemis at the site of Olympia was excavated in 2002. Faunal material from the undisturbed altar

deposits was analysed and published by Benecke (2006). The domesticated assemblage was dominated by sheep (*Ovis aries*) and cattle (*Bos taurus*). In both cases, all elements were recovered from both taxa with the notable exception of femur bones and a reduced proportion of caudal vertebrae. This was postulated to relate to the removal of the thighs and chine during the sacrifice process. This was compared to data from the sanctuaries of Artemision of Ephesos, Eretria in Euboea, Apollo at Halieis and Heraion on Samos, which provided similar evidence for a dominance of sheep (at Ephesos) and the removal of thighs and chine during sacrifice (Benecke, 2006:156). Biometric data were not included in the published report, but were kindly provided by Dr. Benecke upon request.

The sanctuary of Poseidon at Kalaureia is located on the island of Poros just north of the Peloponnesian coast in the Saronic Gulf. Material from the Late Helladic to Roman periods was excavated from the late 1990s to 2012. Faunal material was analysed and published by Mylona *et al.* (2013; Penttinen *et al.* 2009). Measures used in this study come from Archaic and Classical deposits in areas D and H.

**Fig. 1.** Locations of sites given in Table 1.

The Kabiren sanctuary near Thebes was excavated in 1956, 1959 and the 1960s and yielded material from the Classical to Roman periods. Analysis of the faunal material was carried out by Boessneck (1973). He noted that cattle from this site were larger *vis a vis* those of the Middle Bronze Age site of Argissa-Magula in Thessaly and compared the sheep (on the basis of withers heights) to the Merino breed (Boessneck, 1973:12, 15). Publication of the material discriminated between those remains from the Classical, Hellenistic and Roman periods, allowing for the use here only of the measures from the Classical and Hellenistic periods.

The settlement of Messene is located at the northern margin of the Messenian Gulf in the southwestern Peloponnese region of Messene. Excavations from 1990 to 1991 yielded material from the eighth centuries BC to the end of the second century AD, which was analysed and published by Nobis (1994). Measures published from the Late Geometric/Archaic and Hellenistic samples only were used in this study.

The settlement of Kassope is located near the Ionic coast of Epirus and dates to the fourth–first centuries BC. The site was excavated from 1977 to 1981. Faunal material was analysed and published by Friedl (1984) under the direction of Boessneck (1994). Material used here dates to the fourth century BC.

The sanctuary of Poseidon and Amphitrite on the island of Tenos dates from the fourth to second centuries BC (contemporary with Kassope and the majority of material from Messene). The material used in this study was excavated in the 1970s and comes from an area of street bordering the stoa, and also from the sanctuary's kitchens. The analysis and publication carried out by Leguilloux (1999), which found a high taxonomic representation of cattle (*Bos taurus*) in comparison to other Poseidon sanctuaries (Leguilloux, 1999:429–32).

In order to accurately compare colonial and non-colonial domesticated populations, samples were selected from sites in southern Italy which were dated either securely before the period of colonisation, or after its onset. In order to avoid biometrical influence from Roman livestock in the measured samples, all site samples used were dated prior to the fourth century BC. The single exception to this is the sanctuary at Pantanello (the solitary sanctuary of the southern Italian sites), which contains some material dating up to the third century BC. This was retained due to its proximity to other sites studied (including the slightly earlier Incoronata and the contemporaneous Eraclea Lucana and Pomarico Vecchio), but the late end-of-use date for the sample does not preclude Roman influence.

The settlement of Termito is located roughly 7 km from the Ionic coast of the Salento peninsula, on the plain of Metaponto next to the Cavone river. It is situated on a hill some two hundred metres above sea level commanding a view of the area extending to that of the entire Salento peninsula on a clear day (Bianco, 1982:69). The site was excavated from 1973 into the 1980s and evidenced several finds of Mycenaean (LHIIIB and LHIIIC) and Protogeometric ceramics. The site dates to the Later Bronze Age in the local chronology (Bianco, 1982:75). Faunal material from this Late Bronze Age occupation was analysed and published by Bökönyi (2010).

The settlement of Torre Mordillo is located on the western coast of southern Italy, on the Ionian coastline of northern Calabria. It is roughly 1 km from the confluence of the Esaro and Coscile rivers and occupies a plateau commanding a view across the plain of Sybaris to the sea coast. The site was occupied from the Middle Bronze Age until the Iron Age (ending c. eighth century BC). Excavations of the settlement were conducted from 1987 to 1990, the results of which were published by Trucco and Vagnetti (2001). Aegean-type ceramic sherds were recovered from this site, the majority of which appear to be locally produced imitations (Jones 2001:334). The analysis and publication of faunal material by Tagliacozzo and Curci (2001) considered material from the Middle

and Later Bronze Ages. Material used in this study comes from Late and Final Bronze Age portions of the published material.

The settlement of Timpone della Motta is located atop a foothill facing the plain of Sybaris 2 km south-west of the modern village of Francavilla Marittima in Calabria. Excavations were carried out from 1991 and are ongoing. Faunal material from the Middle Bronze to Early Iron Ages was analysed and published by Elevelt (2012). Both Torre Mordillo and Timpone della Motta are located near to the Greek colony of Sybaris (founded c.720 BC) although the studied samples pre-date the colony (Elevelt, 2012).

The Iron Age/Archaic settlement of Incoronata is an indigenous village in the chora of the Greek colony of Metaponto (Metapontum). It is located on the plateau of a hill along the south side of the Basento river. The site was occupied from at least the ninth century BC to the later seventh/sixth centuries BC (De Siena, 1990:83). Excavations were carried out more-or-less simultaneously with those of Pantanello and the remainder of the Metaponto chora (in the 1980s) and continue up to the present day. Incoronata was believed from earlier interpretations to have been an indigenous settlement which was removed and replaced by an Ionian Greek emporion which was then replaced by Achaean Greek settlers from Sybaris who founded a colony there. This traditional interpretation was hotly contested by more recent 1980s excavations and interpretations by De Siena (1990:88) who argues for cultural continuity at this site from the Bronze Age of throughout the later period of Incoronata “greca”. The site is therefore of a somewhat contested interpretation, with the current prevailing theory seeing it as an indigenous village with some Greek contact and imported elements of material culture right up until it disappeared as a settlement (Coleman Carter, 2006:6). Faunal material from this site (from the earlier years of excavation) dating from the eighth to sixth centuries BC was analysed by Bökönyi (2010).

The indigenous settlement of Pomarico Vecchio is located twenty-three kilometres from the colony of Metaponto, along the banks of the Basento River (Barra Bagnasco, 1997:1). The site was excavated from 1982 to 1986 and dates to the fourth century BC (Barra Bagnasco, 1997:4). Faunal material from these excavations was analysed by Aimar (1997).

The Greek colony of Eraclea Lucana (or Heraclea in Lucania) is located along the Ionian coast of Calabria in southern Italy. Material studied here dates roughly from the seventh to fourth centuries BC, was excavated between 1986 and 1993 and was analysed and published by Wilkens and Delussu (2002).

The Greek sanctuary at Pantanello dates from the sixth to third centuries BC. The site was excavated along with two other rural sanctuaries in the area of Metaponto from 1974 to 1993. This site is located roughly 3 km southwest of the colony of Metaponto (Coleman Carter, 2006:5). This sanctuary, coupled with the nearby indigenous sites of Incoronata (eighth to sixth centuries BC) and Termito (14th–11/10th centuries BC) allow for an examination of domesticated varieties in all three site categories (pre-colonial indigenous, colonial indigenous and colony) from not only southern Italy but from an extremely narrow geographical area. It is for this reason that the sanctuary was included in this study, despite the fact that its chronology, continuing up to the third century BC, is one century too young for the previously aforementioned cut-off line.

## 2.1. Biometrical techniques

In order to minimise inter-observer variation in measurements, only those studies which employed the standardised measurements developed by Boessneck and von den Driesch (von den Driesch, 1976) were used here. Biometrical data were compared for sheep (*Ovis aries*) and cattle (*Bos taurus*) between the studied

**Table 2**

Measures taken for standard animals used in this study. The sheep standard animal used is a modern adult male mouflon (*O. orientalis*) collected by A.J. Legge<sup>†</sup>. The standard animal measurements used for cattle are average values of elements measured from skeletons of two oxen from the Roman villa of Nickelsdorf in Austria dated to the 3rd–5th century AD (Pucher, 2006). All measurements follow the abbreviations given by von den Driesch (1976) and are given in millimetres (mm).

<i>Ovis orientalis</i>					<i>Bos taurus</i>				
Element	Measure	mm	Measure	mm	Element	Measure	mm	Measure	mm
Humerus	GL	160.5	BT	29.6	Humerus	GL	338.5	BT	88.6
Radius	GL	172.0	Bp	32.5	Radius	GL	320.3	Bp	95.7
	BFp	29.2	Bd	31.7		BFp	88.0	Bd	87.1
Metacarpal	GL	138.1	Bp	24.3	Metacarpal	GL	213.4	Bp	69.1
Femur	GL	199.5	GLc	193.5	Femur	GLc	386.0	Bd	111.0
	Bp	49.4	Bd	41.6					
Tibia	GL	237.5	Bd	28.6	Tibia	GL	399.0	Bd	71.6
Metatarsal	GL	150.6	Bp	22.4	Metatarsal	GL	247.8	Bp	57.5
Astragalus	GLI	31.3	Bd	20.0	Astragalus	GLI	74.3	Bd	50.5
Calcaneus	GL	60.7			Calcaneus	GL	156.8		
Phalanx 1	GLpe	40.9	Bp	12.0	Phalanx 1	GLpe	65.6	Bp	35.2

sites according to site categories and chronology. These taxa were chosen as they are common in all sites studied and contributed the most numerous measurements. Remains of *Ovis aries* were differentiated from those of the morphologically similar *Capra hircus* according to the criteria given by Boessneck (Boessneck, 1969; Boessneck et al. 1964) and Zeder and Lapham (2010). The smaller number of measures available from the less well represented goats (*Capra hircus*) and pig (*Sus scrofa domesticus*) are not considered here due to insufficient sample sizes.

Measurements were compared through analysis of size-index scaled Log Standard Index values (hereafter LSI). LSI is frequently used as a means by which to expand sample sizes through the translation of 'raw' measurements into indices of size variation from a standard animal or population of animals. This allows for the comparison of a single data set per proportion (length or breadth, following Davis (1996)) per taxon from each site, as opposed to multiple assessments of these per element.<sup>8</sup> Several techniques can be utilised to standardise measures of bones, the most common being the Log Standard Index or LSI described by Meadow (1999) using the formula  $LSI = [\log(x) - \log(m)] \times 100$  where  $x$  is the measure of the archaeological specimen and  $m$  is the corresponding measure of the standard animal or population mean. Measures from the standard animals used in this study are given in Table 2.

For some sites sample sizes remained small even with LSI scaling. The LSI values are given here for all sites from which biometrical data was available (although a sufficient sample size was not necessarily available for both taxa considered). Small samples are included even though not considered large enough for a rigorous comparison of populations. They are included here solely to demonstrate that the few measures available fall within the same size range (though not intended to be taken as representative of the full potential range of population variation) as other sites in the same category containing acceptable sample sizes. Statistical comparisons between samples were made only for those sites from which 5 or more LSI values were obtained.

Variation in body size for both sheep and cattle was compared using both bone lengths and breadths. Bone lengths are more greatly affected by sexual dimorphism – particularly for castrates. This variation in sexual dimorphism by limb proportion can be seen when measures for modern adult (fully fused bones only) Shetland sheep females, males and castrates (Popkin et al., 2012) are translated into LSI values and directly compared (Table 3). Sexual

variation in mean length LSI values can be seen to be greater than that of sexual variation in breadth LSI values. The influence of sexual dimorphism on long bone lengths also LSI values of length depending on the contributing sexual proportions of each assemblage. It is for this reason that LSI values of breadth are separately examined and in this case can be considered a more independent indicator of population (rather than sexual) variation. Comparison of LSI values for bone breadth and length, as used here, can therefore aid in determining changes to livestock population body size. In order to reduce the influence of sexual dimorphism upon measurements of bone breadth, highly dimorphic measurements (such as the distal breadths of metapodials) were not included in this analysis. This was done to remove the influence of sexual variation as much as possible from breadth LSI values. Measures of bone depth (e.g. Dp and Dd following von den Driesch, 1976) have not been compared, as these comprised a much smaller sample size from the sites considered here (and were not reported for several sites). Published measures used as the standard for *Bos taurus* (Pucher, 2006) additionally did not include depth values from which to calculate depth LSI values for cattle.

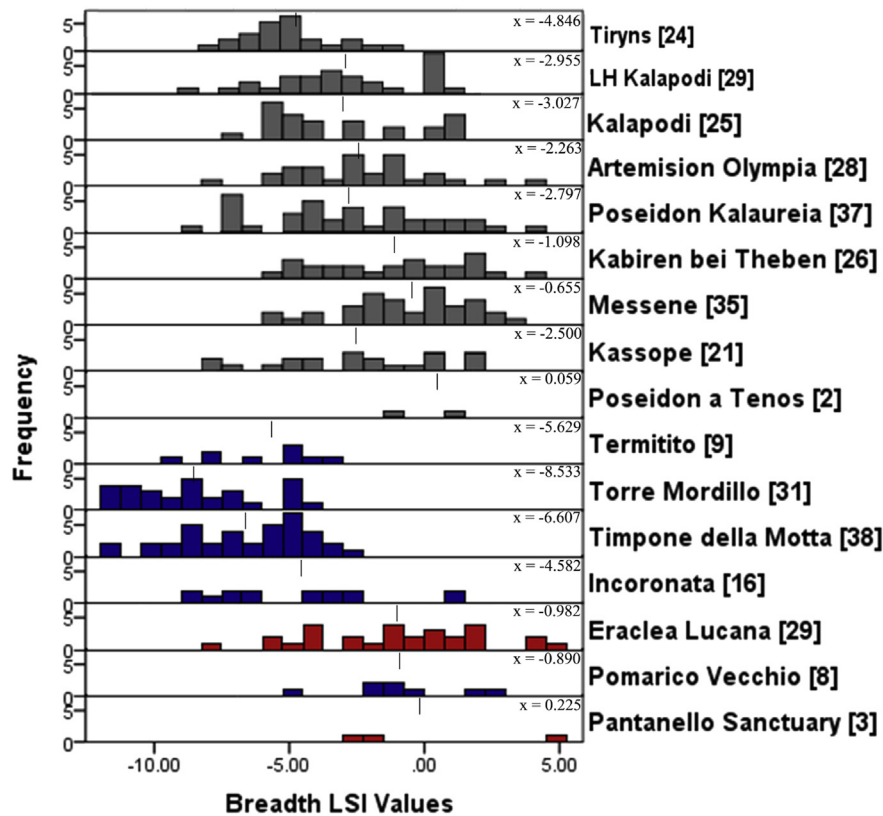
The quantity of tooth measurements available from the sites used in this study was insufficient to determine indications of size variation within and between populations. In addition, published measurements for many sites used here did not provide biometric data for teeth, severely hampering the comparative utility of dental measures. Due to this paucity of data – particularly from published sources – the tooth size data set is too small to be of use here. For this reason, biometrical comparisons of sheep and cattle between sites of Greece and southern Italy have been made using postcranial remains only.

LSI distributions for sheep and cattle were compared in three ways. The range (minimum and maximum values) and distribution of values for each site were compared in separate histograms for length and breadth. The mean values for each site were also compared. These are given in Figs. 2–5 as well as in Table 3. The coefficient of variation was also calculated for each proportional LSI distribution and is given in Table 3. These calculations were used to determine if sites sampled for this study contained more than one variety of sheep or cattle. Recent studies (Popkin et al., 2012) have suggested that high coefficients of variation (CVs) are indicative of either change in the size of a livestock variety during the chronological phase of the sampled biometrical assemblage, or the presence of more than one variety of livestock. While Popkin et al. (2012) suggest the threshold of variation for a single variety (or breed in the case of the modern Shetland sheep sample used) is a CV or six (or higher for determining the presence of multiple varieties or biometric change within the sample chronology). This calculation was made using the coefficients of variation for individual elements. A

<sup>8</sup> This standardisation of size indices across multiple elements is particularly useful for sites with smaller samples, as comparisons of common elements, such as the astragalus or distal tibia, would reduce the measurement sample at many of the sites in this paper to below ten, below five, or to none at all.

**Table 3**  
Summary LSI data for cattle (*Bos taurus*) and sheep (*Ovis aries*) from the sites studied. Sites have been grouped by category and period. Colony sites are marked with an asterisk (\*). L LSI refers here to LSI values of length (Gl), B LSI refers to LSI values of breadth (Bp or Bd). The symbol x designates the mean, s the standard deviation and CV the coefficient of variation.

A		Period		Proportion		n	x		Range		s	CV
Ovis aries												
Greece												
Tiryns	Late Helladic III	L LSI	26			-5.819			-9.684 to -0.665	2.772	7.684	
		B LSI	24			-4.846			-8.103 to -1.454	1.710	2.923	
Kalapodi	Late Helladic III-Submycenaean	L LSI	10			-4.786			-8.668 to -0.418	2.846	8.099	
		B LSI	29			-2.955			-8.530 to 1.148	2.647	7.007	
	Geometric-Classical	L LSI	10			-4.035			-7.559 to 1.634	2.917	8.509	
		B LSI	25			-3.027			-7.058 to 1.494	2.750	7.563	
Artemision Olympia	Archaic	L LSI	5			-3.169			-5.383 to 0.139	2.127	4.525	
		B LSI	28			-2.263			-8.162 to 4.458	2.665	7.101	
Poseidon Kalaureia	Archaic-Classical	L LSI	10			-4.700			-8.392 to -1.124	2.558	6.542	
		B LSI	37			-2.797			-8.308 to 3.892	3.207	10.285	
Kabiren bei Theben	Classical-Hellenistic	L LSI	6			-3.619			-7.950 to 1.500	3.024	9.143	
		B LSI	26			-1.098			-5.578 to 3.764	2.781	7.733	
Messene	Archaic-Hellenistic	L LSI	9			-4.179			-6.418 to -1.842	1.535	2.357	
		B LSI	35			-0.655			-5.843 to 3.386	2.470	6.102	
Kassope	Hellenistic	L LSI	13			-4.740			-8.440 to -1.120	2.433	5.922	
		B LSI	21			-2.500			-8.052 to 2.093	3.136	9.832	
Poseidon a Tenos	Hellenistic	L LSI	1			-			-0.139	-	-	
		B LSI	2			0.059			-0.955, 1.072	1.433	2.054	
Southern Italy												
Termitito	Late Bronze Age	L LSI	4			-8.475			-10.040 to -7.745	1.053	1.110	
		B LSI	8			-5.629			-9.500 to -2.228	2.487	6.186	
Torre Mordillo	Final Bronze Age	L LSI	7			-8.088			-10.815 to -5.621	1.765	3.117	
		B LSI	31			-8.533			-12.047 to -4.396	2.407	5.795	
Timpone della Motta	Early Iron Age	L LSI	14			-8.123			-12.080 to -4.530	2.484	6.172	
		B LSI	38			-6.607			-11.843 to -2.919	2.333	5.442	
Incoronata	Archaic	L LSI	6			-8.039			-10.964 to -4.110	3.535	12.498	
		B LSI	16			-4.582			-8.458 to 1.066	3.171	10.055	
*Eraclea Lucana	Archaic-Hellenistic	L LSI	5			-1.289			-3.315 to 0.282	1.495	2.236	
		B LSI	29			-0.982			-8.103 to 4.736	3.160	9.985	
Pomarico Vecchio	Hellenistic	L LSI	2			-0.509			-1.842, 0.825	1.886	3.556	
		B LSI	8			-0.890			-4.546 to 2.601	2.196	4.824	
*Pantanello	Classical-Hellenistic	L LSI	1			0.961			-	-	-	
		B LSI	3			0.225			-2.388 to 5.115	4.238	17.964	
B												
Site		Period		Proportion		n	x		Range		s	CV
Bos taurus												
Greece												
Tiryns	Late Helladic III	L LSI	13			-8.233			-12.333 to -4.364	2.402	5.770	
		B LSI	18			-12.357			-16.800 to -8.360	3.017	9.103	
Kalapodi	Late Helladic III-Submycenaean	L LSI	10			-7.241			-11.883 to -4.828	2.262	5.117	
		B LSI	13			-9.772			-13.157 to -6.695	2.037	4.150	
	Geometric-Classical	L LSI	1			-			-7.261	-	-	
		B LSI	4			-8.700			-12.252 to -3.119	3.994	15.948	
Poseidon Kalaureia	Archaic-Classical	L LSI	6			-7.379			-9.674 to -3.875	2.342	5.483	
		B LSI	6			-7.114			-9.938 to -3.466	2.296	5.273	
Kabiren bei Theben	Classical-Hellenistic	L LSI	22			-3.402			-6.486 to 0.264	1.887	3.561	
		B LSI	21			-4.818			-9.938 to 2.749	3.575	12.783	
Messene	Archaic-Hellenistic	L LSI	26			-2.881			-10.727 to 2.195	3.277	10.736	
		B LSI	26			-4.819			-11.492 to 1.118	3.831	14.678	
Kassope	Hellenistic	L LSI	53			-2.217			-5.849 to 4.046	2.484	6.172	
		B LSI	90			-3.794			-9.584 to 3.158	3.104	9.634	
Poseidon a Tenos	Hellenistic	L LSI	11			-2.993			-6.114 to -0.916	1.666	2.776	
		B LSI	17			-4.703			-9.584 to 1.432	3.144	9.888	
Southern Italy												
Termitito	Late Bronze Age	L LSI	1			-8.537			-	-	-	
		B LSI	5			-13.075			-16.575 to -10.123	2.824	7.974	
Torre Mordillo	Final Bronze Age	L LSI	23			-10.499			-14.245 to -7.125	2.250	5.040	
		B LSI	31			-11.684			-18.613 to -5.518	3.620	13.108	
Timpone della Motta	Early Iron Age	L LSI	13			-11.084			-14.652 to -7.136	2.410	5.810	
		B LSI	13			-13.317			-18.671 to -7.525	4.095	16.767	
Incoronata	Archaic	L LSI	9			-7.162			-9.984 to -5.500	1.657	2.744	
		B LSI	13			-9.948			-14.688 to -5.984	2.669	7.124	
*Eraclea Lucana	Archaic-Hellenistic	L LSI	48			-4.476			-9.484 to 0.702	2.541	6.457	
		B LSI	40			-6.570			-15.484 to -1.131	3.614	13.064	
Pomarico Vecchio	Hellenistic	B LSI	6			-7.678			-14.860 to -0.998	4.954	24.541	
		L LSI	27			-1.966			-5.833 to 2.140	2.365	5.593	
*Pantanello	Classical-Hellenistic	B LSI	46			-2.867			-10.308 to 3.707	3.296	10.866	
		L LSI	26			-1.966			-5.833 to 2.140	2.365	5.593	
C												
Summary LSI values from Popkin et al 2012												
Sex		Proportion		n		x		Range		s		CV
Female	L LSI	1056		-8.500		-14.778 to -0.977		2.071		4.289		
Male	L LSI	376		-5.060		-12.667 to 0.097		2.350		5.524		
Castrate	L LSI	272		-4.963		-9.463 to -0.883		1.755		3.081		
Female	B LSI	924		-4.514		-10.670 to 1.549		1.985		3.939		
Male	B LSI	329		-2.075		-7.883 to 5.260		2.301		5.296		
Castrate	B LSI	238		-2.349		-6.831 to 4.877		2.099		4.407		
Male and Female	L LSI	1432		-7.781		-14.778 to 0.097		2.463		6.065		
Male and Female	B LSI	1253		-3.480		-10.670 to 5.260		2.701		7.298		
All	L LSI	1704		-7.331		-14.778 to 0.097		2.579		6.653		
All	B LSI	1491		-3.140		-10.670 to 5.260		2.728		7.443		



**Fig. 2.** Distribution of breadth (Bp or Bd) LSI values for *Ovis aries* from sampled sites of Greece and southern Italy. The sites given in this table have been colour-coded by site category as in Table 1. The number of samples measured for each site is given in brackets. The mean ( $\bar{x}$ ) of each sample is given and its position marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

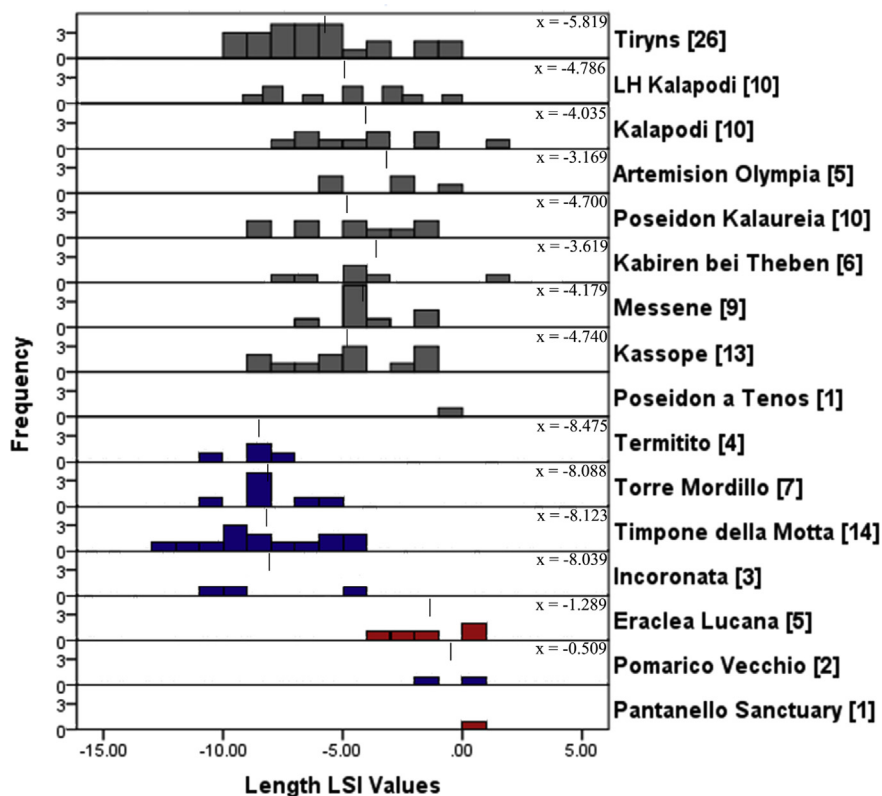
comparison of length and breadth LSI values for males, females and castrates (Table 3) yielded CVs of 6.653 for length and 7.443 for breadth. A comparison of males and females (excluding castrates) yielded CVs of 6.065 for length and 7.298 for breadth. This places the threshold for determining the presence of either size change or multiple varieties of livestock using a combination of elements higher than the six (or seven) suggested by Popkin *et al.* (2012). Separate comparative studies were not available for cattle. As bovines, cattle should show similar patterns of size variation within across the sexes of a given variety to those calculated for sheep. Specific calculations of variety or breed coefficients of variation however are not at present available for comparison, however.

### 3. Results

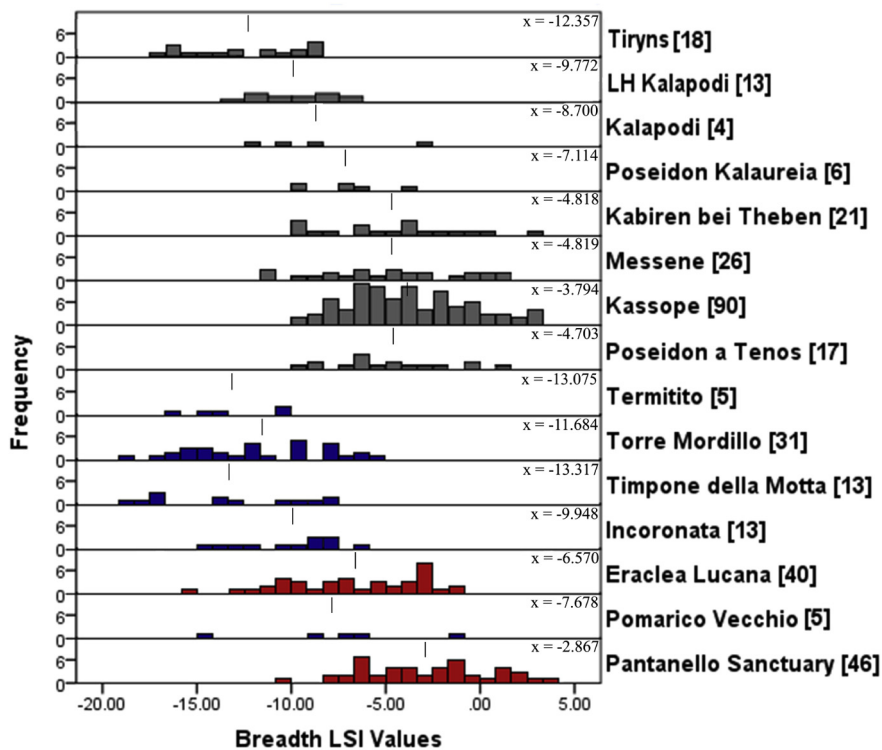
Comparisons of LSI values of bone length (Gl) and breadth (Bp or Bd) for sheep and cattle can be seen in Figs. 3–5 and Table 3. Despite the wide geographic and temporal range of sites from Greece, it is notable that biometric profiles for sheep are surprisingly similar across this area from the Archaic period onwards. The earlier samples from Tiryns (Late Helladic IIIB–C or c.1335–1125 BC) and Kalapodi (c.1130–1030 BC) are more variable, with sheep from Tiryns of a smaller population size distribution than those of Kalapodi. Sheep biometric data from Protogeometric–Classical periods of Kalapodi correspond in size to the earlier sample from this site as well as the other Archaic–Hellenistic site samples from Greece. Comparisons between sites dated to these periods indicate population groups of sheep within Greece which do not greatly vary between sampled sites. Hellenistic period samples (Kabiren bei Theben, Messene, Kassope and Poseidon a Tenos) demonstrate a similar distribution of population size ranges

but with what appears to be slight geographic variation in the mean size of sheep. Several of these samples contain high variation in sheep measures (high CV values). This may suggest the presence of multiple varieties within the sample (Poseidon Kalaureia, Kabiren bei Theben and Kassope) which are biometrically similar.

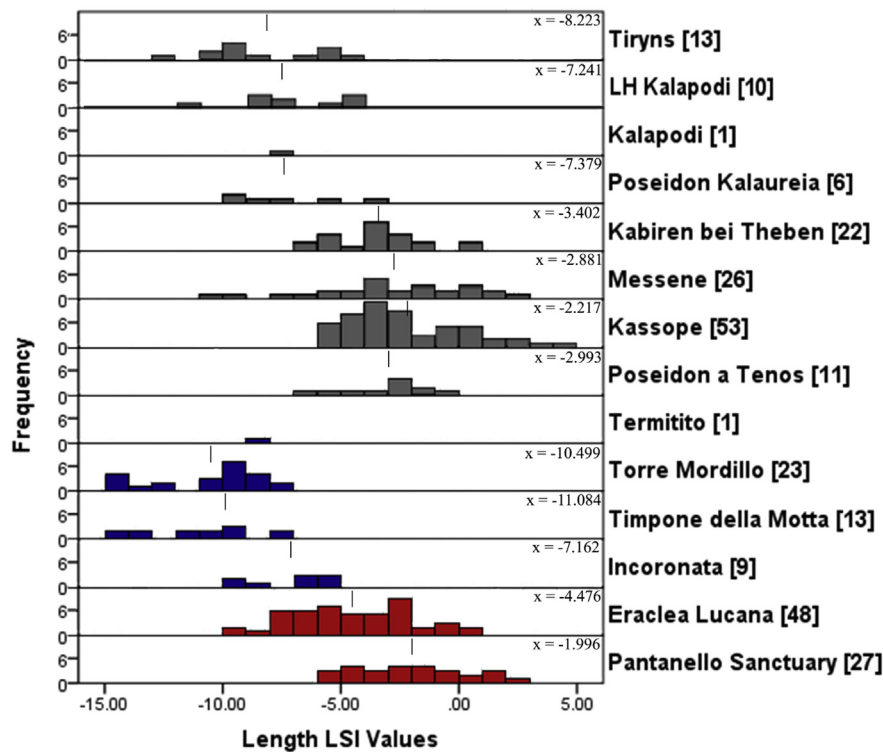
Populations of sheep from sites in southern Italy also do not vary greatly from one another in overall size, albeit with greater variation in mean LSI breadths between individual settlements in comparison with Greek sites. Comparisons of size between biometric site samples from Greece and southern Italy display distinct differences. Contemporaneous populations of sheep from Late Bronze and Early Iron Age sites (Termitito, Torre Mordillo and Timpone della Motta in southern Italy and Tiryns and Kalapodi in Greece) demonstrate larger sheep in Greece than southern Italy. Greek colonies in southern Italy are also distinct from pre-colonial sites in size. These data demonstrate the presence of regional varieties of sheep which can be distinguished between Greece and southern Italy. These data additionally indicate an increase in the size of sheep in areas of Greek colonisation. The Archaic period site of Incoronata (8th–6th centuries BC) which has been argued to be a ‘creolized’ or ‘hybrid’ indigenous site (Antonaccio, 2005). Size patterning for sheep at Incoronata more closely approximates indigenous forms of sheep, but the studied sample contains a wide range of variation (CVs of 10.055 and 12.498) overlapping both indigenous and Greek/Greek colony size ranges. A high level of variation in sheep measures from Eraclea Lucana also suggests the presence of multiple biometrically similar varieties. The Hellenistic period sample from the settlement of Pomarico Vecchio (with CVs of 3.556 and 4.824 suggesting the presence of one variety only) contains a ‘Greek’-sized population of sheep corresponding to those found at colonies and not at earlier indigenous sites.



**Fig. 3.** Distribution of length (GL) LSI values for *Ovis aries* from sampled sites of Greece and southern Italy. The sites given in this table have been colour-coded by site category as in Table 1. The number of samples measured for each site is given in brackets. The mean ( $x$ ) of each sample is given and its position marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



**Fig. 4.** Distribution of breadth (Bp or Bd) LSI values for *Bos taurus* from sampled sites of Greece and southern Italy. The sites given in this table have been colour-coded by site category as in Table 1. The number of samples measured for each site is given in brackets. The mean ( $x$ ) of each sample is given and its position marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



**Fig. 5.** Distribution of length (GL) LSI values for *Bos taurus* from sampled sites of Greece and southern Italy. The sites given in this table have been colour-coded by site category as in Table 1. The number of samples measured for each site is given in brackets. The mean ( $\bar{x}$ ) of each sample is given and its position marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

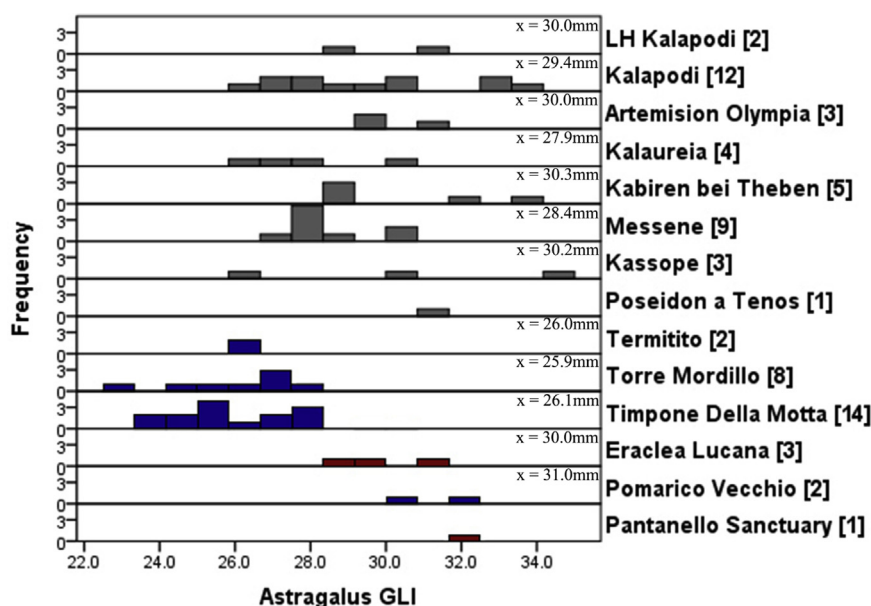
Biometrical patterning for cattle demonstrates a different pattern to that of sheep. Comparisons between contemporaneous site samples from Greece and southern Italy demonstrate a progressive increase in the size of cattle in both regions from the Late Bronze Age through the Archaic period with population size ranges stabilising from the Classical/Hellenistic period. Cattle in southern Italy from the Late Bronze and Early Iron Age sites are within the size range of cattle from Tiryns, and those from Incoronata are within the size range of cattle from both periods sampled at Kalapodi. It is worth noting here that the standard animal measures used for cattle come from a robust pair of Roman oxen. Cattle measures from Late Bronze Age sites of both Greece and southern Italy are smaller in breadth than length in comparison with these oxen (see Fig. 3), suggesting the presence of animals more gracile by comparison. The off-set between LSI values for length and breadth changes slightly through time, suggesting that cattle in both areas were becoming not only larger but more robust. Cattle from southern Italian Greek colony samples (Eraclea Lucana and Pantanello), regardless of the period of site sample (Archaic, Classical or Hellenistic) more closely correspond in size to cattle from contemporaneous periods in Greece. Due to the pattern of increase in population size distributions of cattle in both Greece and southern Italy during the studied periods it is not possible to determine if this size increase in southern Italy was the specific result of Greek colonisation or that of a general chronological pattern in both regions. The small sample from Pomarico Vecchio suggests both a broad range of variation in the size of cattle from this site (CV of 24.541) as well as a smaller mean cattle size in comparison with contemporaneous samples from both Greece and southern Italy (see Fig. 4).

Trends evidenced from comparisons of LSI data were further investigated through comparison of astragalus lengths (GLI) from the sites studied. This measure was used as it is (at least for sheep)

the least affected by age, sex or nutritional status (Popkin et al., 2012:1780). Comparisons of length measures for astragali (GLI) can be seen in Figs. 6 and 7. These measures also indicate an increase in the size of sheep at Greek colonies *vis-a-vis* earlier indigenous sites. Sheep from colonies and Pomarico Vecchio contain sheep astragali of c.30 mm in length (matching those from sites in Greece) as opposed to c.26 mm at pre-colonial indigenous sites. This corresponds to an increase in average astragalus GLI of 4 mm, or an increase in size of roughly 15%. A similar comparison of astragalus lengths (GLI) for cattle suggests an increase in size at sites from southern Italy between 52.1 mm (Torre Mordillo) and 61.0 mm (Termitito) for the Late Bronze Age and 70–72 mm (Eraclea Lucana and Pantanello Sanctuary) during periods of Greek colonisation. This suggests a mean increase in astragalus lengths of 9–20 mm or roughly 16–35%.

### 3.1. Size uniformity and change

These LSI data (summarised in Table 3) were subjected to the Kruskal–Wallis ANOVA to determine if the observed population variations were statistically significant. For these tests the null hypothesis used ( $H_0$ ) was that LSI values compared came from population groups of the same size animals. The  $p$ -value was set at 0.01. The results of these tests are given in Tables 4 and 5. The Greek sites demonstrated statistically significant uniformity (null hypothesis accepted) in size distributions of sheep when sites were compared against one another. The pre-colonisation sites of southern Italy likewise demonstrated statistically significant uniformity in size distributions. The Greek colonies (and Pomarico Vecchio) contained sheep of a statistically different population body size distribution from those of pre-colonisation sites but which were not significantly different from those of sites within Greece. The Archaic period sample from Incoronata did not contain

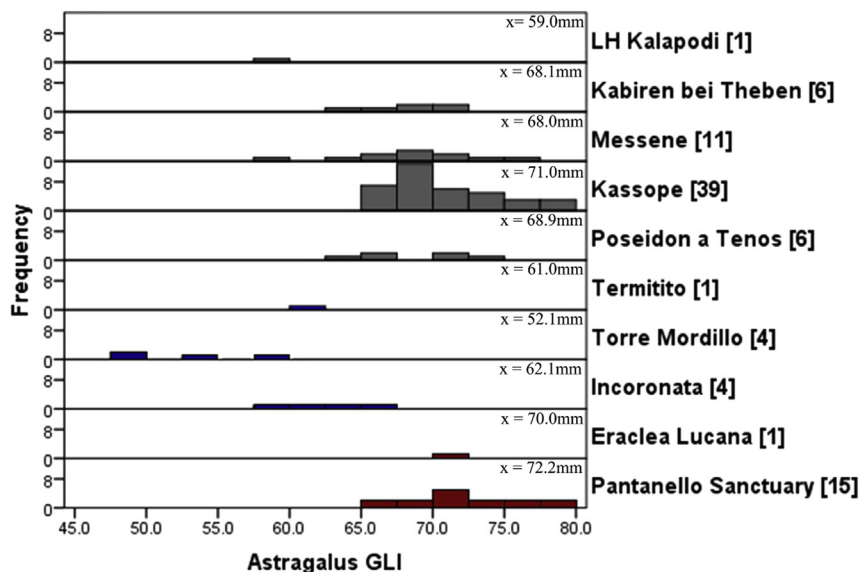


**Fig. 6.** Comparison of astragali lengths (GLI) for *Ovis aries* from sites studied. Mean astragalus length measures ( $x$ ) are given in mm. All measures were taken following von den Driesch (1976) and sites are colour-coded as in Fig. 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

enough measures for sheep for a rigorous conduction of the Kruskal–Wallis test and did not display statistical differences in population size distribution to any category of sites.

LSI distributions for cattle display statistically significant differences in population size distribution between chronological periods rather than between site categories. Cattle from Late Bronze Age Greek site samples (Tiryns and Kalapodi) demonstrate significant differences in population size distributions from Greek sites dating to the Classical and Hellenistic periods while the small Archaic-Classical sample from Poseidon Kalaureia does not display statistical difference to any Greek site regardless of the sample period. Cattle from Tiryns, Kalapodi and Poseidon Kalaureia cannot be statistically differentiated from pre-colonisation period site samples of southern Italy. Cattle from Greek colony sites in

southern Italy are in the majority statistically different in population size distributions from those site samples dating prior to the onset of Greek colonisation in this area (Termito, Torre Mordillo and Timpone della Motta). The small sample available from Incoronata corresponds to samples from southern Italian pre-colonisation sites in demonstrating statistical difference from Classical and Hellenistic period samples both from Greece as well as Greek colonies but not from the small sample of Pomarico Vecchio. The Hellenistic site of Pomarico Vecchio displays cattle of a smaller size to those found in Greece during this period (Fig. 4) but the small sample size precludes any rigorous statistical comparisons. The evidence for a change in the size of cattle seen both within Greece and southern Italy indicates a chronological pattern of ‘improvement’ of this taxon, but from the present data it cannot be determined if this was



**Fig. 7.** Comparison of astragali lengths (GLI) for *Bos taurus* from sites studied. Mean astragalus length measures ( $x$ ) are given in mm. All measures were taken following von den Driesch (1976) and sites are colour-coded as in Fig. 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4

Results of Kruskal–Wallis tests on breadth LSI value distributions for *Ovis aries*. *P*-values for all sites with sample sizes greater than 5 are given in, although those with sample sizes below twenty are marked with an asterisk as these are below the recommended threshold (Zar, 2010:214). Those sites containing statistically significant ( $p \geq 0.01$ ) differences in population size distributions are highlighted in bold.

Site	Tiryns	LH Kalapodi	Kalapodi	Artemision Olympia	Poseidon Kalaureia	Kabiren bei Theben	Messene	Kassope	Termitito	Torre Mordillo	Timpone della Motta	Incoronata	Eraclea Lucana	Pomarico Vecchio
Tiryns	-	<b>0.009</b>	0.037	<b>0.000</b>	0.008	<b>0.000</b>	<b>0.000</b>	0.010	0.542	<b>0.000</b>	<b>0.007</b>	0.727	<b>0.000</b>	<b>0.000</b>
LH Kalapodi	0.009	-	0.828	0.380	0.892	0.030	<b>0.001</b>	0.630	<b>0.004</b>	<b>0.000</b>	<b>0.000</b>	0.161	0.023	0.050
Kalapodi	0.037	0.828	-	0.219	0.730	0.012	<b>0.002</b>	0.460	<b>0.005</b>	<b>0.000</b>	<b>0.000</b>	0.110	0.014	0.044
Artemision Olympia	<b>0.000</b>	0.380	0.219	-	0.516	0.119	0.010	0.911	<b>0.005</b>	<b>0.000</b>	<b>0.000</b>	0.033	0.102	0.159
Poseidon Kalaureia	0.008	0.892	0.730	0.516	-	0.046	<b>0.002</b>	0.728	<b>0.006</b>	<b>0.000</b>	<b>0.000</b>	0.102	0.032	0.115
Kabiren bei Theben	<b>0.000</b>	0.030	0.012	0.119	0.046	-	0.599	0.177	<b>0.001</b>	<b>0.000</b>	<b>0.000</b>	0.009	0.879	0.913
Messene	<b>0.000</b>	<b>0.001</b>	<b>0.002</b>	0.010	<b>0.002</b>	0.599	-	0.040	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.002</b>	0.671	0.815
Kassope	0.010	0.630	0.460	0.911	0.728	0.177	0.040	-	0.008	<b>0.000</b>	<b>0.000</b>	0.075	0.146	0.241
Termitito*	0.542	<b>0.004</b>	<b>0.005</b>	<b>0.005</b>	<b>0.006</b>	<b>0.001</b>	<b>0.000</b>	0.008	-	0.010	0.354	0.495	<b>0.002</b>	<b>0.002</b>
Torre Mordillo	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.010	-	0.040	<b>0.004</b>	0.438	<b>0.000</b>
Timpone della Motta	<b>0.007</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.354	0.040	-	0.132	<b>0.000</b>	<b>0.000</b>
Incoronata*	0.727	0.161	0.110	0.033	0.102	0.009	<b>0.002</b>	0.075	0.495	<b>0.004</b>	0.132	-	0.010	0.016
Eraclea Lucana	<b>0.000</b>	0.023	0.014	0.102	0.032	0.879	0.671	0.146	<b>0.002</b>	<b>0.000</b>	<b>0.000</b>	0.010	-	0.883
Pomarico Vecchio*	<b>0.000</b>	0.050	0.044	0.159	0.115	0.913	0.815	0.241	<b>0.002</b>	<b>0.000</b>	<b>0.000</b>	0.016	0.883	-

concurrent with Greek colonisation or part of a wider chronological trend affecting both regions. It is interesting to note that the small sample from Pomarico Vecchio – while insufficient for robust statistical comparisons – lags behind its contemporaries in both Greece and southern Italy in mean cattle size. This may suggest that management practices, 'improvements' or improved varieties were not incorporated as fully at this site as in Greece and its colonies.

### 3.2. Observations on the data

Analysis of the measurements of sheep and cattle from Magna Graecia has demonstrated significant evidence for an increase in the size of livestock in Greek colonies. It is suggested here that this increase in the size of livestock resulted either from the translocation of Greek sheep and cattle to colonies or local

improvements to livestock in areas of colonisation. The sites studied provide clear evidence for sheep from Greek sites of a larger variety than those present in southern Italy as early as the Late Bronze Age. There is some evidence within Greece for regional variation in the size of sheep during the Late Bronze Age (Tiryns and Kalapodi) and the Hellenistic Period (Kabiren bei Theben, Messene, Kassope and Poseidon a Tenos) although the overall pattern for Greece is of larger livestock than seen in southern Italy. Greek colonies in southern Italy contain sheep of a distinctly larger population size distribution than those from pre-colonisation sites. Sheep in Greek colonies of southern Italy correspond in size to those found in Greece in all periods compared, suggesting that sheep at Greek colonies were either translocated from Greece or were locally improved subsequent to the onset of Greek settlement in southern Italy.

**Table 5**

Results of Kruskal–Wallis tests on breadth LSI value distributions for *Bos taurus*. *P*-values for all sites with sample sizes greater than 5 are given in, although those with sample sizes below twenty are marked with an asterisk as these are below the recommended threshold (Zar, 2010:214). Those sites containing statistically significant ( $p \geq 0.01$ ) differences in population size distributions are highlighted in bold.

Site	Tiryns	LH Kalapodi	Poseidon Kalaureia	Kabiren bei Theben	Messene	Kassope	Poseidon a Tenos	Termitito	Torre Mordillo	Timpone della Motta	Incoronata	Eraclea Lucana	Pomarico Vecchio	Pantanello Sanctuary
Tiryns	-	0.028	<b>0.003</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.551	0.210	0.447	<b>0.003</b>	<b>0.000</b>	0.021	<b>0.000</b>
LH Kalapodi*	0.028	-	0.035	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.043	0.279	0.029	0.281	<b>0.005</b>	0.217	<b>0.000</b>
Poseidon Kalaureia*	<b>0.003</b>	0.035	-	0.129	0.147	0.025	0.161	<b>0.006</b>	0.020	<b>0.005</b>	0.065	0.624	0.855	<b>0.004</b>
Kabiren bei Theben	<b>0.000</b>	<b>0.000</b>	0.129	-	0.991	0.381	0.789	<b>0.001</b>	<b>0.000</b>	<b>0.000</b>	<b>0.001</b>	0.116	0.255	0.050
Messene	<b>0.000</b>	<b>0.000</b>	0.147	0.991	-	0.384	0.720	<b>0.002</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.138	0.163	0.047
Kassope	<b>0.000</b>	<b>0.000</b>	0.025	0.381	0.384	-	0.183	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.001</b>	0.059	0.061
Poseidon a Tenos*	<b>0.000</b>	<b>0.000</b>	0.161	0.789	0.720	0.183	-	<b>0.001</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.226	0.157	0.019
Termitito*	0.551	0.043	<b>0.006</b>	<b>0.001</b>	<b>0.002</b>	<b>0.000</b>	<b>0.001</b>	-	0.213	0.961	0.023	<b>0.002</b>	0.076	<b>0.000</b>
Torre Mordillo	0.210	0.270	0.020	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.213	-	0.084	0.341	<b>0.000</b>	0.131	<b>0.000</b>
Timpone della Motta*	0.447	0.029	<b>0.005</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.961	0.084	-	0.048	<b>0.000</b>	0.026	<b>0.000</b>
Incoronata*	0.028	0.898	0.065	<b>0.001</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.023	0.341	0.048	-	<b>0.006</b>	0.218	<b>0.000</b>
Eraclea Lucana	<b>0.000</b>	<b>0.005</b>	0.624	0.116	0.138	<b>0.001</b>	0.226	<b>0.002</b>	<b>0.000</b>	<b>0.000</b>	<b>0.006</b>	-	0.691	<b>0.000</b>
Pomarico Vecchio*	0.021	0.217	0.855	0.255	0.163	0.059	0.157	0.076	0.131	0.026	0.218	0.691	-	0.015
Pantanello Sanctuary	<b>0.000</b>	<b>0.000</b>	<b>0.004</b>	0.050	0.047	0.061	0.019	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	0.015	-

Cattle from Greek colonies in southern Italy are larger than those found at pre-colonisation sites. However, the pattern observed for a progressive chronological increase in the size of cattle within Greece precludes any specific interpretations from these data as to whether this increase resulted from Greek colonisation in southern Italy or was part of a wider trend in the region.

Incoronata – as a site with pre-colonisation indigenous occupation layers (not studied), mixed Greek architecture and material culture – is considered indicative of an indigenous settlement which interacted with nearby Greek colonies but which retained indigenous domesticated varieties with some evidence for the selected adoption of imported livestock or management practices rather than wholesale replacement. The later Hellenistic period settlement of Pomarico Vecchio demonstrates more distinct evidence for the increased size of both sheep and cattle. Biometric profiles of local livestock evidence changes to livestock management practices (or the adoption of imported domesticated varieties) which may relate to interaction between colonists and indigenous groups in the colonial environment by at least this later period. This is particularly evident in the biometrical profile for sheep.

The Greek sanctuary at Pantanello contains both sheep and cattle of the largest size in comparison to both sites from southern Italy and Greece. As this site is both the latest sample (with an end-of-use date in the 3rd century BC) and the only currently studied sanctuary sample it cannot from these data be conclusively determined whether livestock were selected for the sanctuary on the basis of size or demonstrate a further improvement to livestock later in the Hellenistic period. The very small sample for sheep does not provide enough data for any firm conclusions, but the LSI distributions for cattle are evenly distributed in both length and breadth. These distributions do not suggest a strong sex bias for cattle from Pantanello, but rather the presence of a slightly larger population contributing to the sample. The LSI off-set between measures of length and breadth for cattle is the smallest seen from any of the sites compared here, suggesting that Pantanello cattle were more robust still than those of slightly earlier sites from Greece as well as southern Italy. In comparison with the Roman oxen used here as standard measures, cattle astragali from Pantanello averaged 72 mm, or 3% smaller than the Roman standard animals (74.3 mm).

#### 4. Discussion

From the present data there is considerable evidence for livestock improvement occurring in Greece and Greek colonies prior to and during the last millennium BC. The increased size of sheep in Late Bronze Age Greece in relation to those of the same period in southern Italy may have resulted from natural variation. However, these areas are not distant geographically, climatically or ecologically. Natural differences in the quality of local environments and grazing lands are still present, but the broad geographic similarity in sheep size within Greece over the Late Bronze Age to Hellenistic period compared with those of southern Italy suggests that this size discrepancy resulted from specific practices in the management or breeding of this taxon. From both textual sources and iconographic observations by [Ryder \(1983\)](#) there is evidence of sheep production in Greece orientated towards the production of fine wool. This is not to say that all sheep from Greek sites were of a fine-fleeced type, or that the fine-fleeced sheep referenced by Classical, Hellenistic and Roman sources (see above) were present at Late Hellenistic sites (although see [Halstead \(1999\)](#) and [Rougémont \(2004\)](#) for discussions of Mycenaean sheep management for wool production). The texts discussion in Section 1.1 demonstrate the status of sheep and sheep-rearing within Greece and support the present biometric evidence for Greek improvements to this taxon.

Textual sources cited above suggest that different 'breeds' of livestock were not only recognised but were intentionally interbred or translocated for the production of desired traits, such as improved wool quality. While the present data cannot determine between the translocation or local improvement of sheep, the increase in size of this taxon within colonies concurrent with Greek colonisation – and reaching a size and population distribution closely corresponding to that seen at sites in Greece both during and prior to the period of colonisation – does not rule out the movement of sheep between these areas and strongly indicates the close management of domesticates in both areas studied.

The increased size of sheep contrasts with that of cattle. Sites from both Greece and southern Italy indicate the improvement of cattle, but occurring at a later date than that seen for sheep. The progressive increase in cattle size seen from sites in Greece supports the evidence for both domesticates of livestock management and improvements ([Kron, 2002:59](#)). The larger size of both sheep and cattle at Greek colonies indicate that these 'improvements' were either separately conducted at colony sites from southern Italy or that larger varieties of livestock were imported from Greece.

The more gradual pattern of size increase seen in cattle requires further study. A more detailed understanding of the pattern (both geographic and chronological) of size increase for cattle coupled with an analysis of management patterns at those sites where size changes are first apparent may indicate when and where these larger and more robust cattle were developed and the probable causes and motivations for such improvement. Despite the studies of increasing size of livestock with Roman expansion seen from multiple areas of Europe it is still not clear why livestock in these areas increased in size or whether this was the result of the intentional inter-breeding of animals (although see [Albarella et al. 2008](#) and [Pucher, 2006](#)) or widespread changes to animal management practices. Changes to land management, farming systems and market economies may have encouraged the intensive management or breeding of livestock, as was seen later in the Roman period ([Albarella et al. 2008](#); [Duval et al. 2013](#); [Kron, 2002](#)) and discussed by Hellenistic and Roman sources (e.g. [Aristotle](#); [Columella](#)). Unfortunately, those surviving texts from the Archaic and earlier periods of Greece and southern Italy do not greatly illuminate the productive incentives of stock-rearing.<sup>9</sup>

The close proximity of southern Italy to Greece would make domesticated translocation a feasible option during the settlement of this region whether colonies were initially organised as large-scale ventures or individual piecemeal affairs. Determination as to the level of organisation in early colonial foundation (with regards to the identification of widespread translocation) would require narrower chronological windows than available from the sites presented here. The rate of change in livestock biometric profiles – particularly for sheep – would require analysis of initial occupation phases of colony sites and those in their hinterlands.

The comparison of biometric patterning change in Italy with more widespread colonial foundations – such as those in the Pontic region or western Mediterranean – would provide better indicators of the level of organisation in early colony foundations through a detailed comparative analysis of livestock changes in early occupation layers at sites both from southern Italy as well as these more far-flung regions. This would require not only further analysis of domesticated biometry from narrower chronological

<sup>9</sup> Although see [Halstead \(1999\)](#) and [Rougémont \(2004\)](#) for discussion relating sheep production in the earlier Mycenaean period.

windows (by century or even by layer) for Greek colonies in each of these areas but also a comprehensive comparative analysis of domestic biometry from non-colonial sites contemporaneous with, prior to and following the foundation of Greek colonies in these areas.

Such future analysis would also benefit from the inclusion of dental biometric comparisons as well as the post-cranial comparisons used here. The more conservative nature of teeth in relation to size changes would provide a useful contrast with post-cranial biometry in determining the improvement or movement of livestock (Albarella *et al.* 2008). Initial changes to livestock biometry could be further investigated with regard to the origin of translocated animals through the comparison of isotopic or DNA analysis on identified 'large' animals in early occupation layers.

Changes in the size of domestic varieties within Greece have been seen to occur from multiple sites prior to the Archaic/Classical periods. Further work should be done on livestock biometry in ancient Greece for both taxa considered here – on size changes to sheep throughout the Bronze Age and on cattle during the Submycenaean to Classical periods. As with the process of Greek colonisation, a more detailed understanding of domestic breeding and management practices within Greece would be of value in determining levels of inter-regional interaction during the Late Bronze and Early Iron Ages as well as the development of sheep breeding and management at Mycenaean palatial centres and other Bronze Age sites throughout Greece.

## 5. Conclusions

This study has demonstrated a distinct and significant change in the size of domestic sheep and cattle in southern Italy during the final millennium BC. This size change is also seen in Greece for cattle but not for sheep, which are larger within Greece from as early as the Late Bronze Age. It is argued that this change in the population body size of sheep and cattle within Italy resulted either from the translocation of Greek domestic varieties to colonies or the local development of 'improved' varieties. This change in domestic varieties provides an ideal means by which to incorporate zooarchaeological analyses into studies of Greek colonisation in southern Italy, alongside other current avenues of research into cultural contact and colonisation (e.g. assessments of architecture, ceramics and/or metalwork). It is hoped that this current study will ignite future interest in examining domestic biometry within Greece and its areas of colonisation. There is no specific expectation from our current understanding of Greek colonisation that the patterns seen here would be evident at every Greek colony, or in each region. The continued incorporation of biometric and other zooarchaeological data will, however, add to our understanding of this intricate and multi-varied process.

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